USAFETAC/PR--92/001

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WIND-SPEED PERIODICITY STUDY

for

SHEMYA AFB, ALASKA

by

Capt Christopher A. Donahue

APRIL 1992

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13. Abstract: Describes results of a time series analysis of Shemya AFB, Alaska, in an attempt to identify high frequency periodicities (fluctuations with periods of less than 1 hour) in wind speed at Shemya AFB, Alaska. Peaks in the power spectra at low frequencies were filtered out, and the remaining peaks were tested for significance. None of the peaks in the spectra at high frequencies were found to be significantly different from white noise.

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PREFACE

This study describes the results of USAFETAC Project 920118, "Wind-Speed Periodicity Study for Shemya AFB, Alaska". The analyst was Capt Christopher A. Donahue, USAFETAC/DNO.

The study was in response to a request from SAC/DOWX for a USAFETAC analysis of wind speed data from Shemya AFB, Alaska; specifically, a time series analysis of the data on four Shemya wind recorder rolls. The purpose of the analysis was to determine if evidence of a short term periodicity (with an interval between gusts on the order of 10 minutes) could be identified. The study was conducted in an attempt to use wind-speed observations to confirm the theory that aircraft can land at Shemya during lulls between gusts, which were believed to occur at intervals of about 10 minutes.

Before the analysis was begun, the data on the wind recorder rolls was digitized. Wind speeds were recorded at 2.5-minute intervals. A SAS[1] procedure (PROC SPECTRA) was then used to generate the power spectra from the digitized data. The low and very high frequency waves were then filtered out, and peaks in the remaining spectra were tested for significance.

The results of the analysis indicate that there is no statistically significant short term periodicity in the Shemya wind speed data.

[1]SAS--Statistical Analysis System--Fourth generation computer language used at USAFETAC.

CONTENTS

FIGURES

TABLES

1. INTRODUCTION

1.1 Background. SAC/DOWX tasked USAFETAC to investigate the possible existence of short-term periodicity in wind speeds at Shemya AFB, Alaska. Specifically, they requested that we use spectral analysis to study wind speed data on four wind recorder rolls, and to test the significance of any peaks in the spectra. Spectral analysis shows the contributions of oscillations with various frequencies to the variance of the time series itself (Panofsky and Brier, 1968). Fourier analysis is used to create the spectra of the time series. According to mathematical principles, any series composed of a finite number of observation points can be estimated by a finite series of sine and cosine functions. Fourier analysis is a method of determining the finite series of sines and cosines.

1.2 Focus of the Study. SAC/DOWX was particularly interested in determining whether or not evidence of a periodicity on the order of 10 minutes could be found. This study was conducted in an attempt to use wind-speed observations to confirm the theory that aircraft can land at Shemya during lulls between wind gusts, which were believed to occur at approximately 10-minute intervals.

2. METHODOLOGY

2.1 Data. In order to compute the power spectra, it was first necessary to digitize the data contained on the wind recorder rolls. This task was performed at USAFETAC/OL-A, where wind speeds were recorded in 2.5-minute intervals during the four periods requested by SAC/DOWX. Figures 1-4 show these time series for the four datasets. The highest frequency that can be detected is twice the sampling interval (the "Nyquist frequency"). Since the focus of this study was on periodicities near 10 minutes, the 2.5-minute sampling interval was acceptable. Once the Nyquist frequency was known, the minimum record length necessary to distinguish peaks in the spectra at the desired frequency (those with a period near 10 minutes in this case) could be calculated (Jenkins and Watts, 1968). The minimum record length in this case was calculated to be 2.5 hours. Since the datasets used are at least 12 hours long, this requirement was also satisfied.

2.2 Computing the Spectra. The SAS procedure "PROC SPECTRA" was used to produce the power spectra, which were plotted using SAS/GRAPH. The spectra were first plotted for the full period of each dataset, with the results shown in Figures 5-8. Note that these spectra show large peaks at very low frequencies and occasionally at very high frequencies. Both these peaks are, in all likelihood, products of the sampling technique used to produce the spectra, rather than being indicative of true periodicity in the wind speeds. The peaks at very high frequency (at periods of about 5 minutes, or frequencies of about 12 cycles per hour) are undoubtedly due to "aliasing," a problem that arises from the necessity of taking samples from a continuous time series in order to estimate the spectrum digitally. Aliasing causes sinusoids at frequencies higher than the sampling rate to appear at a lower frequency (Otnes and Enochson, 1972). Since the data was taken at 2.5-minute intervals, the shortest resolvable period was 5 minutes (twice the sampling rate). Any shorter periods in the data would likely be "aliased" to 5 minutes, and contribute to the spectral density at that period. The peaks at low frequencies (periods longer than 1 hour, or frequencies less than 1 cycle per hour) appear to be due to the length of the datasets (which range from 12 to 20 hours).

2.3 Analysis of the Spectra. To determine whether or not there is a periodicity on the order of 10 minutes, peaks in the spectra at periods greater than 1 hour (frequencies less than 1 cycle/hour) and those with periods less than 5.45 minutes (frequencies greater than 11 cycles per hour) were filtered out. The spectra were then plotted again, with the results shown in Figures 9-12. The "Fisher's Kappa" test of significance (computed by PROC SPECTRA) was used on these spectra to see if the peaks in the spectra were significantly different from the largest peaks expected from a purely random spectrum (using a significance level of 0.05).

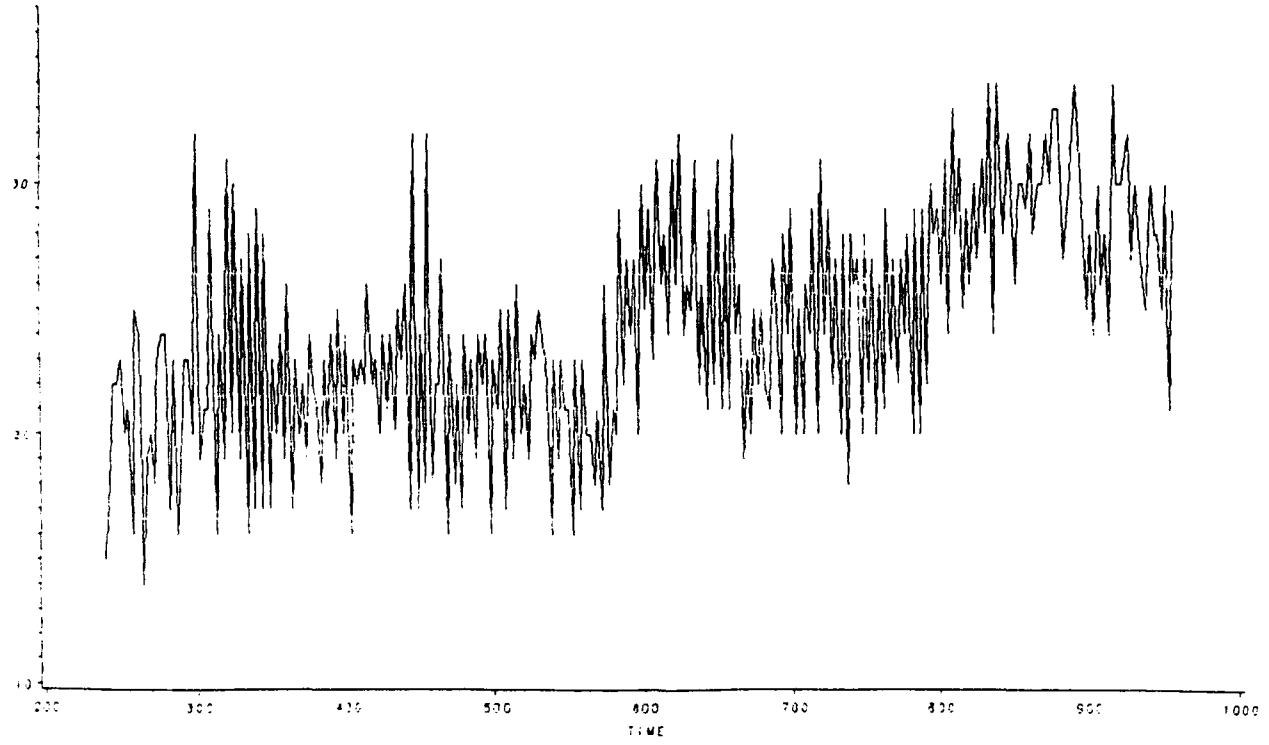

Figure 1. Wind speed (knots) vs. time (minutes) at Shemya, 5 Sep 16Z to 6 Sep 04Z.

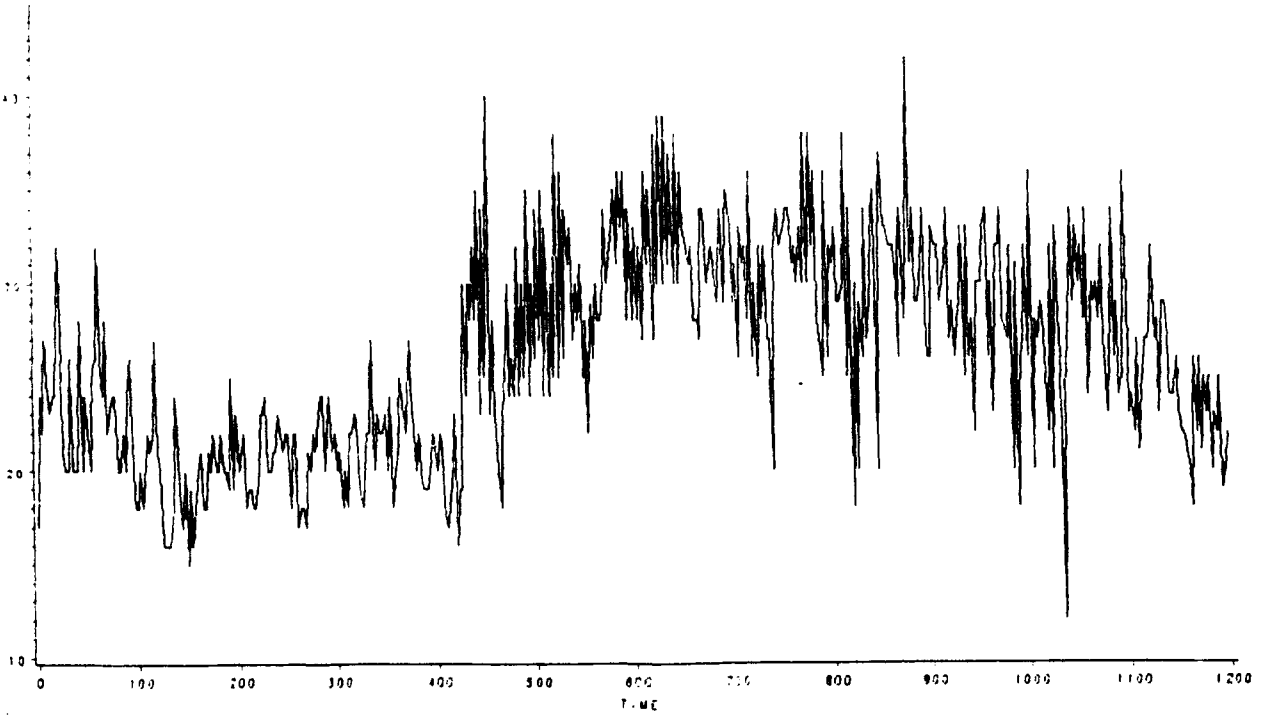

Figure 2. Wind speed (knots) vs. time (minutes at Shemya, 22 Sep 22Z to 23 Sep 08Z.

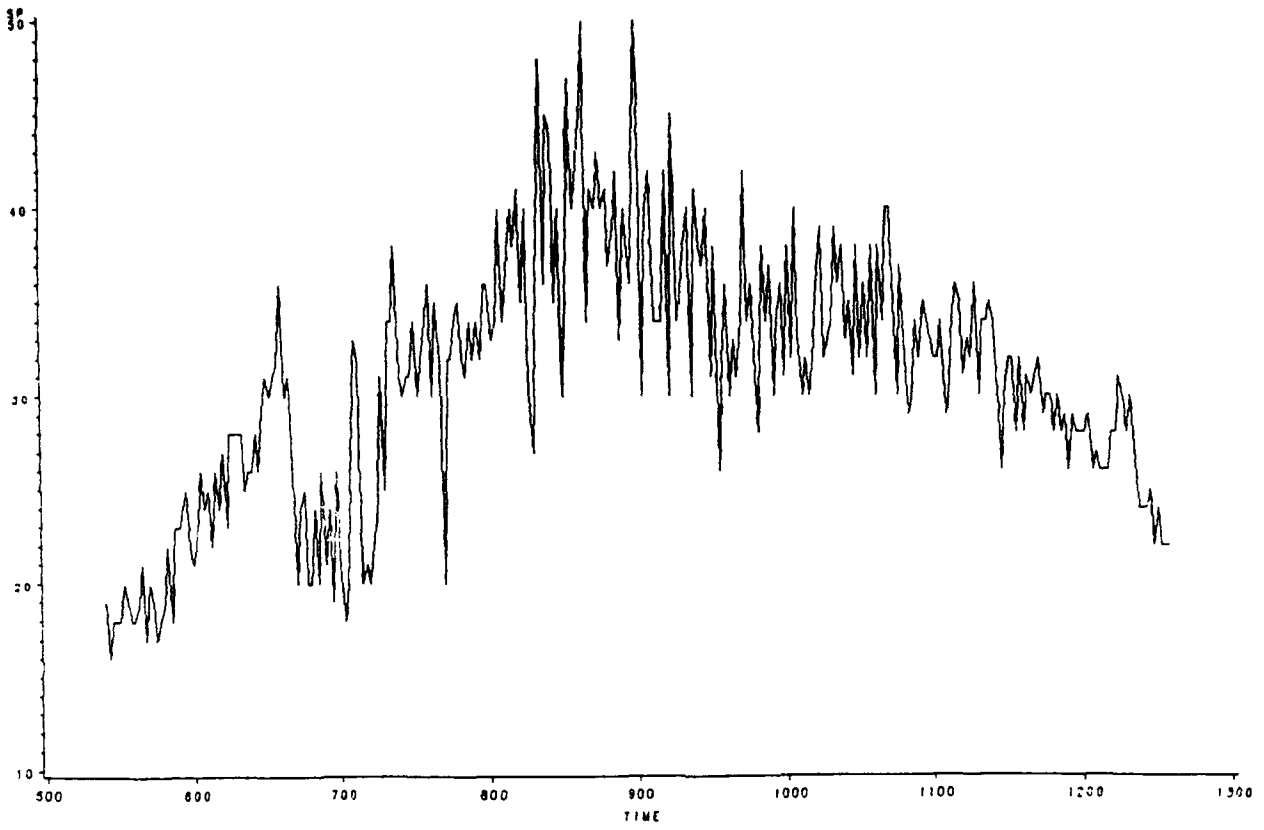

Figure 3. Wind speed (knots) vs. time (minutes) at Shemya, 28 Sep 21Z to 29 Sep 09Z.

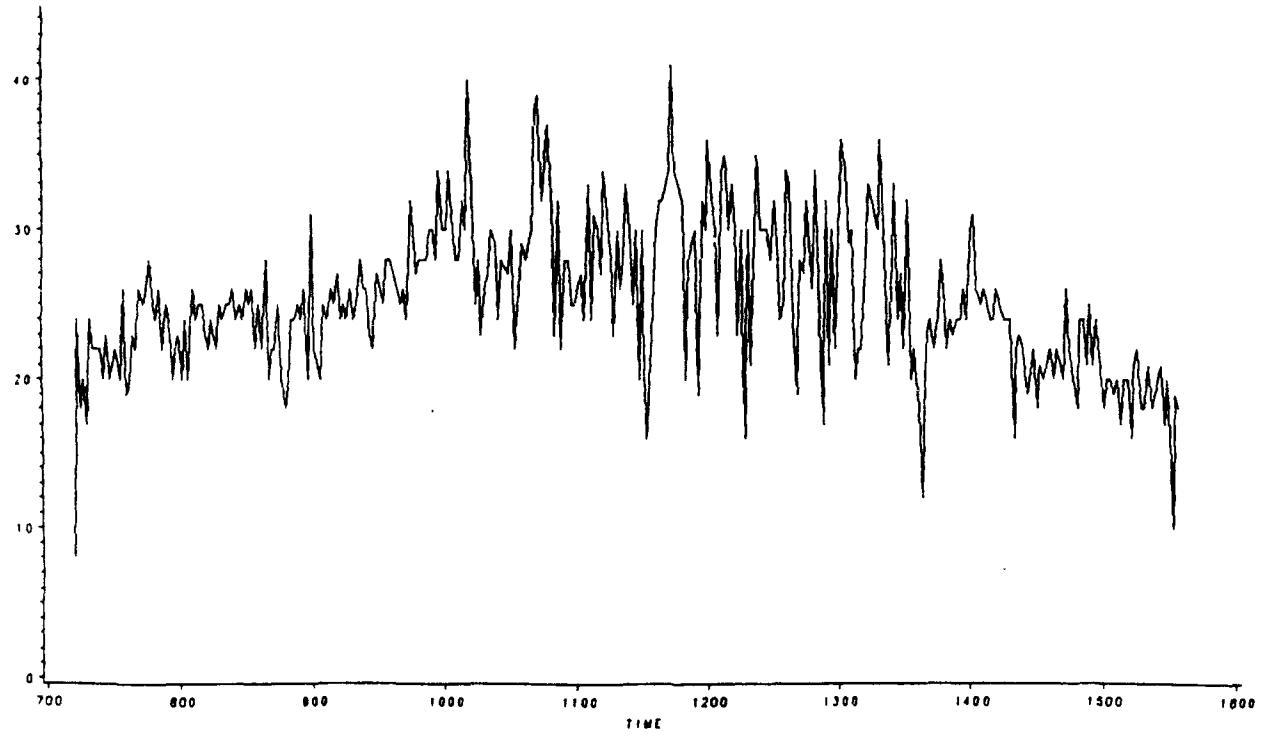

Figure 4. Wind Speed (knots) vs. time (minutes) at Shemya, 5 Oct 00Z to 14Z.

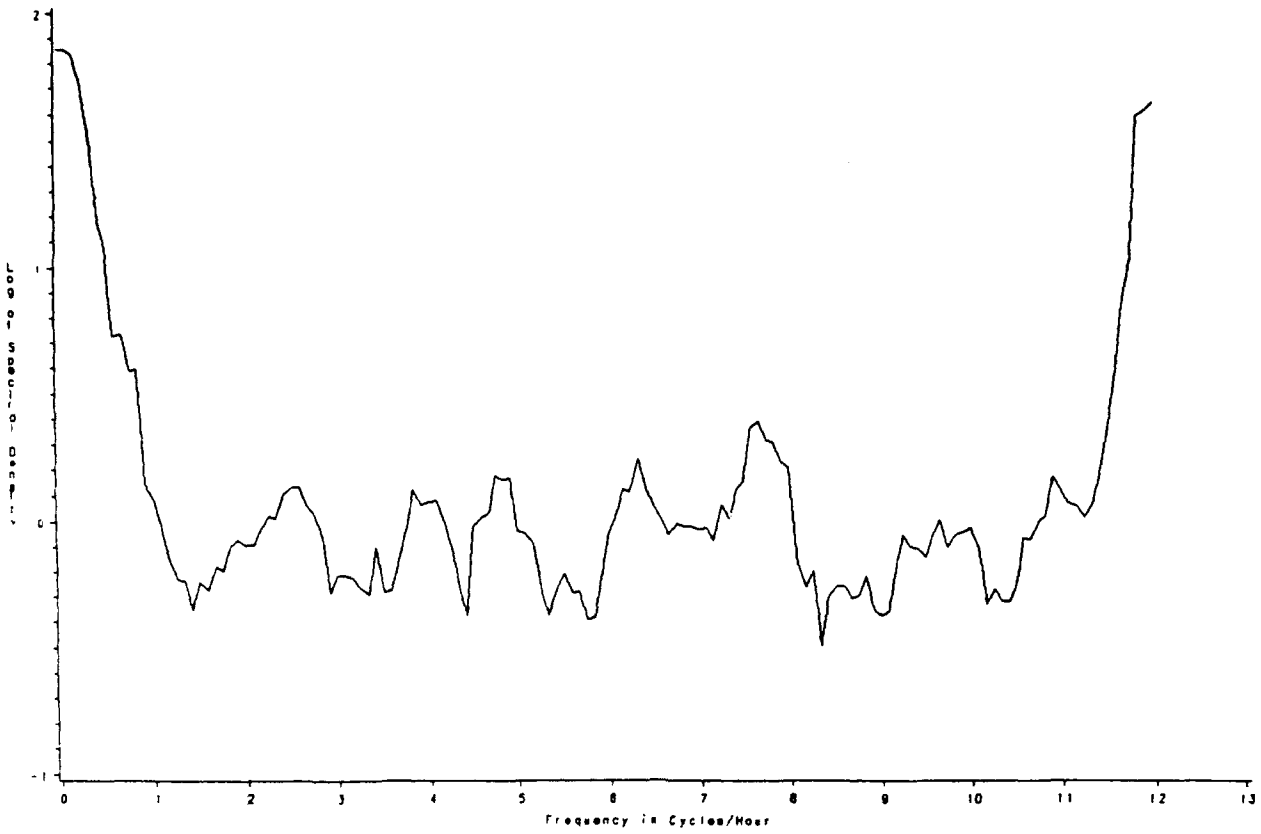

Figure 5. Power spectrum of Shemya wind speeds, 5-6 Sep 91 (full period).

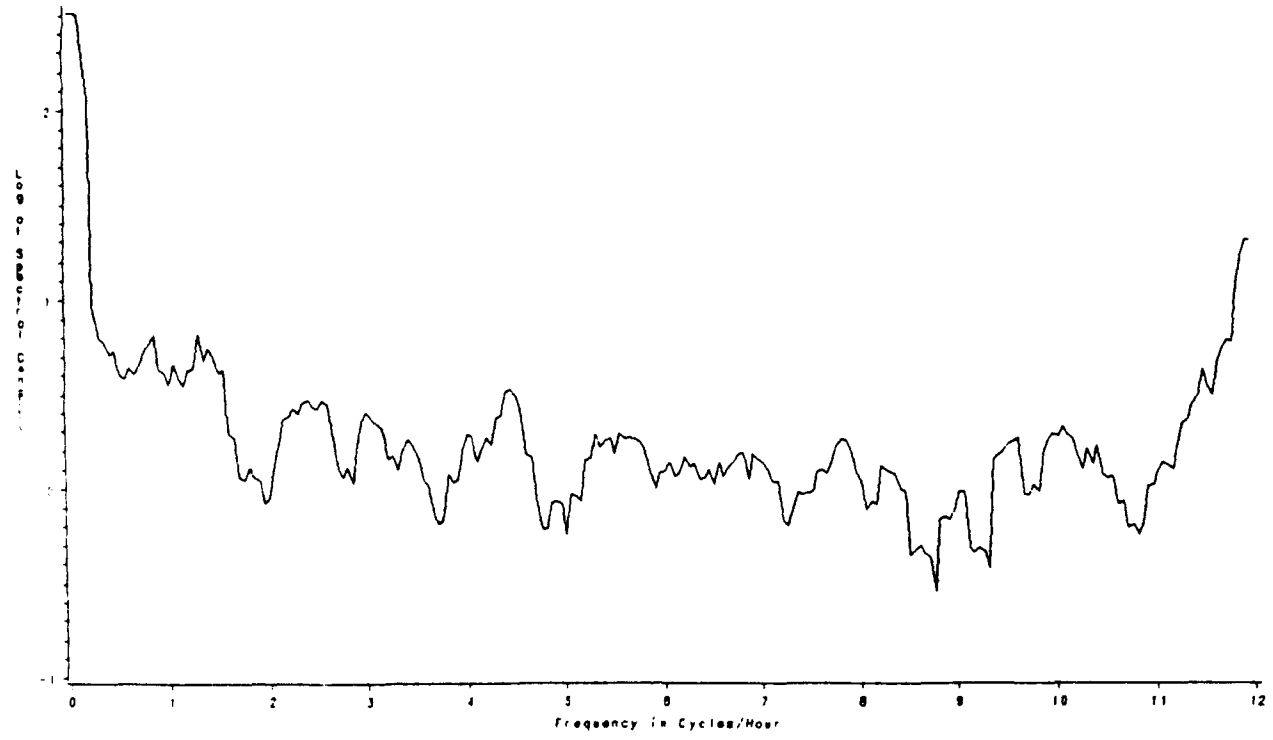

Figure 6. Power spectrum of Shemya wind speeds, 22-23 Sep 91 (full period).

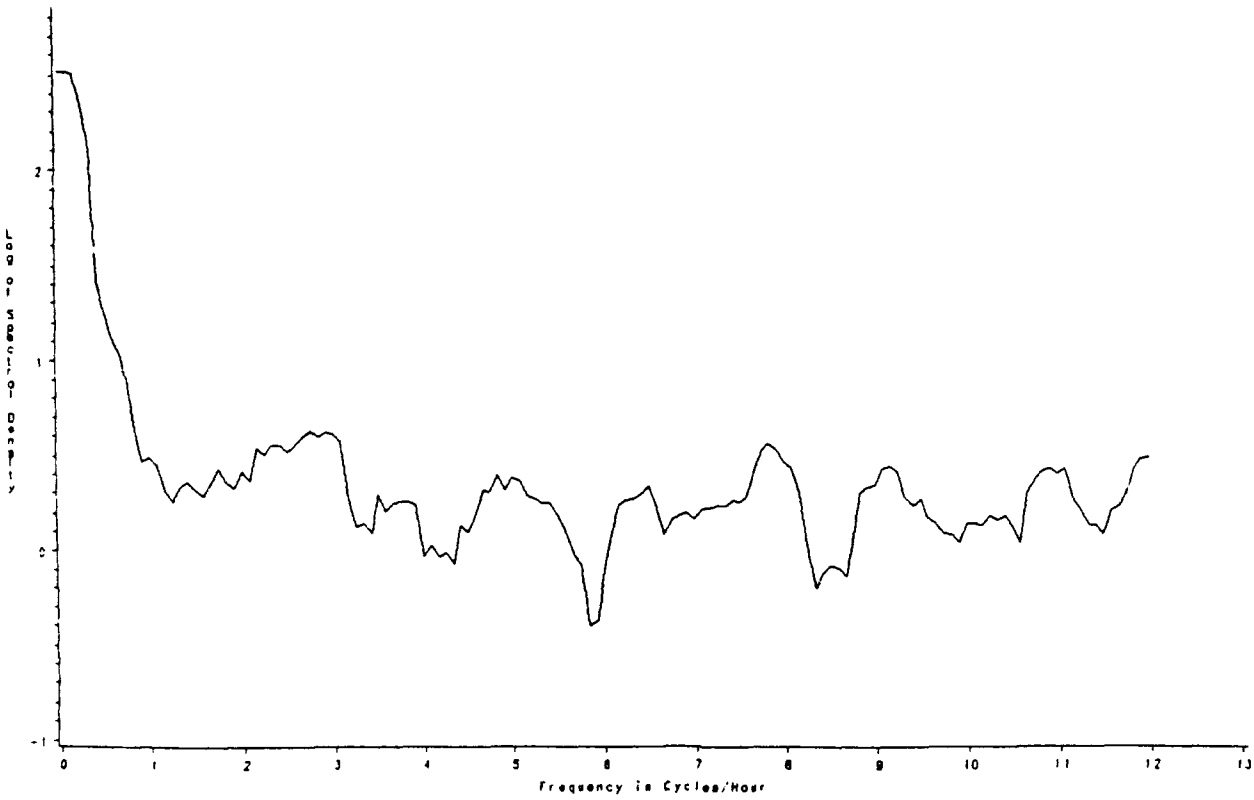

Figure 7. Power spectrum of Shemya wind speeds, 28-29 Sep 91 (full period).

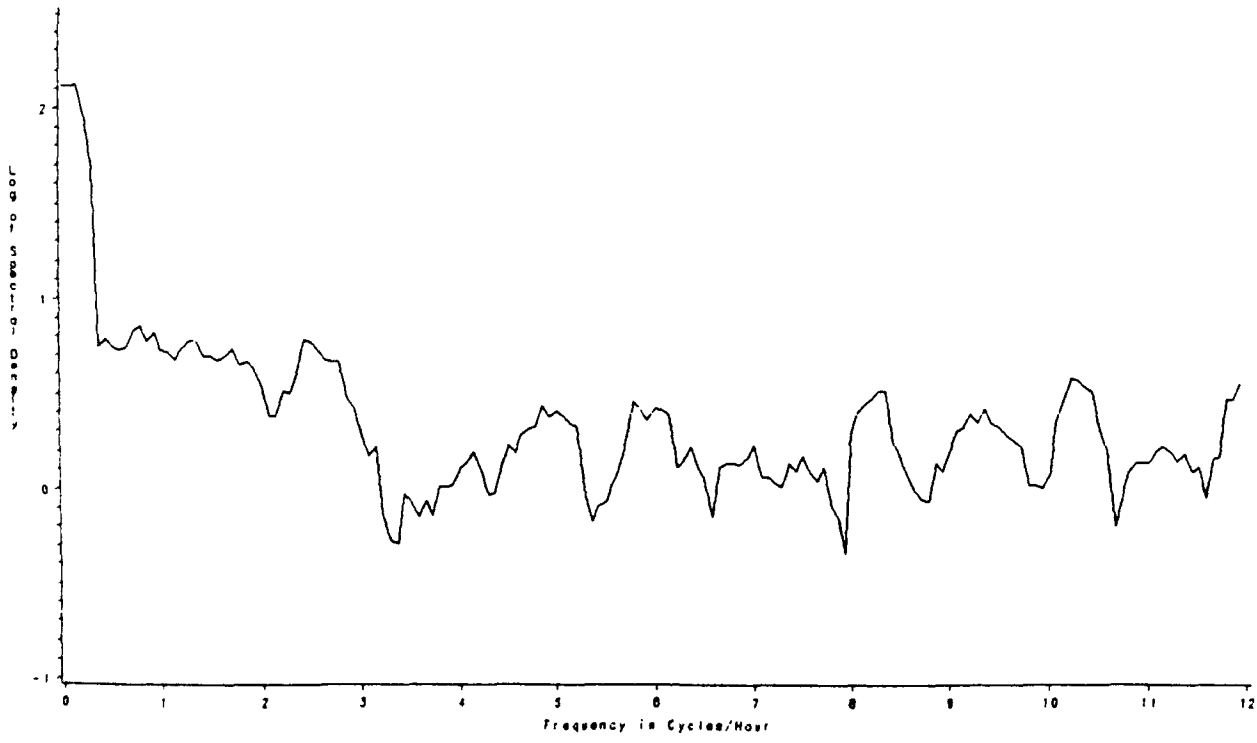

Figure 8. Power spectrum of Shemya wind speeds, 5 Oct 91 (full period).

3. RESULTS.

Inspection of Figures 9-12 reveals that peaks in the spectra occur at a wide range of periods. The most commonly observed "large" peaks occur at around 21-25 minutes, 6-7 minutes, 9-13 minutes, and 43-52 minutes. However, only the peaks at a period near 45 minutes (near 1.5 cycles/hour) from the 28-29 September data set (Figure 10) were found to be significantly different from the largest peak in a white noise spectrum. None of the other peaks passed this significance test. These results are discussed further in the last paragraph of the report. The periods of the four largest peaks from each data set are given in Tables 1-4, along with the results of the test of significance.

TABLE 1. Periods of the four highest peaks from 5-6 Sep 91 dataset (need Kappa > 7.79 for peak to be significant).

Rank	Period (minutes)	Frequency (cycles/hour)	Kappa Value
1	7.7	7.7	6.47
2	12.8	4.7	3.80
3	9.2	6.5	3.30
4	23.3	2.6	2.93

TABLE 2. Periods of the four highest peaks from 22-23 Sep 91 dataset (need Kappa > 8.34 for peak to be significant).

Rank	Period (minutes)	Frequency (cycles/hour)	Kappa Value
1	42.9	1.4	8.88
2	52.2	1.15	8.69
3	13.6	4.4	4.64
4	6.3	9.5	4.23

TABLE 3. Periods of the four highest peaks from 28-29 Sep 91 dataset (need Kappa > 7.79 for peak to be significant).

Rank	Period (minutes)	Frequency (cycles/hour)	Kappa Value
1	21.1	2.8	6.04
2	25.7	2.3	4.91
3	7.6	7.9	3.41
4	48.0	1.25	2.91

TABLE 4. Periods of the four highest peaks from the 5 Oct 91 dataset (need Kappa > 7.94 for peak to be significant).

Rank	Period (minutes)	Frequency (cycles/hour)	Kappa Value
1	23.3	2.6	5.48
2	33.5	1.8	4.43
3	7.35	8.2	4.16
4	5.9	10.2	3.63

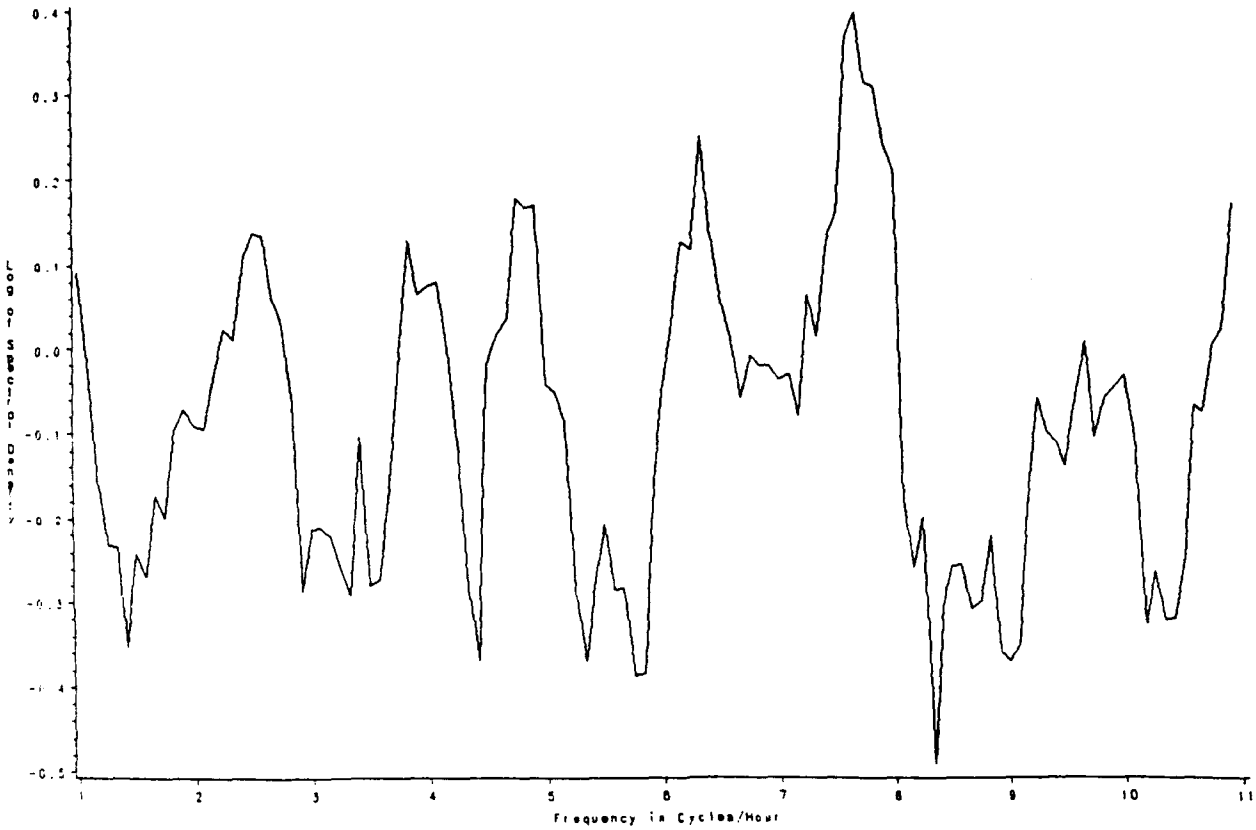

Figure 9. Power spectrum of Shemya wind speeds, 5-6 Sep 91 (1 < freq < 11)

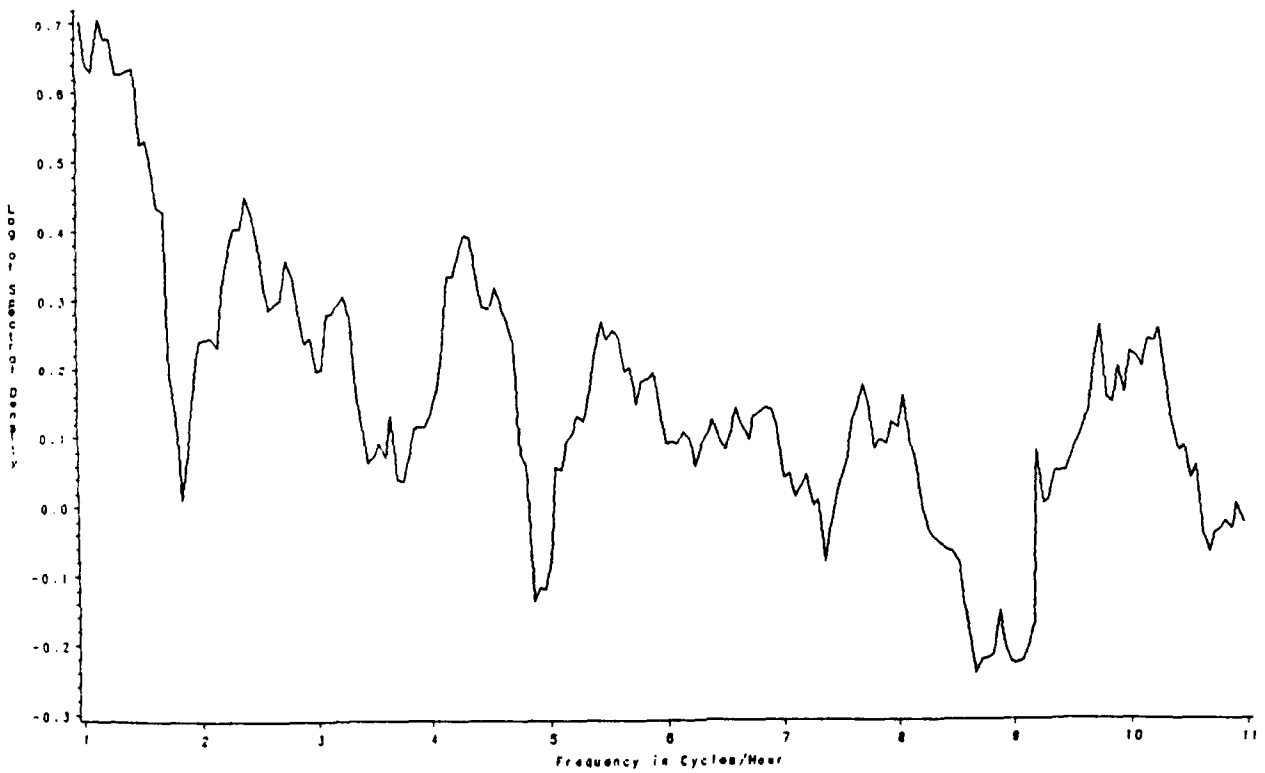

Figure 10. Power spectrum of Shemya wind speeds, 22-23 Sep 91 (1 < freq < 11).

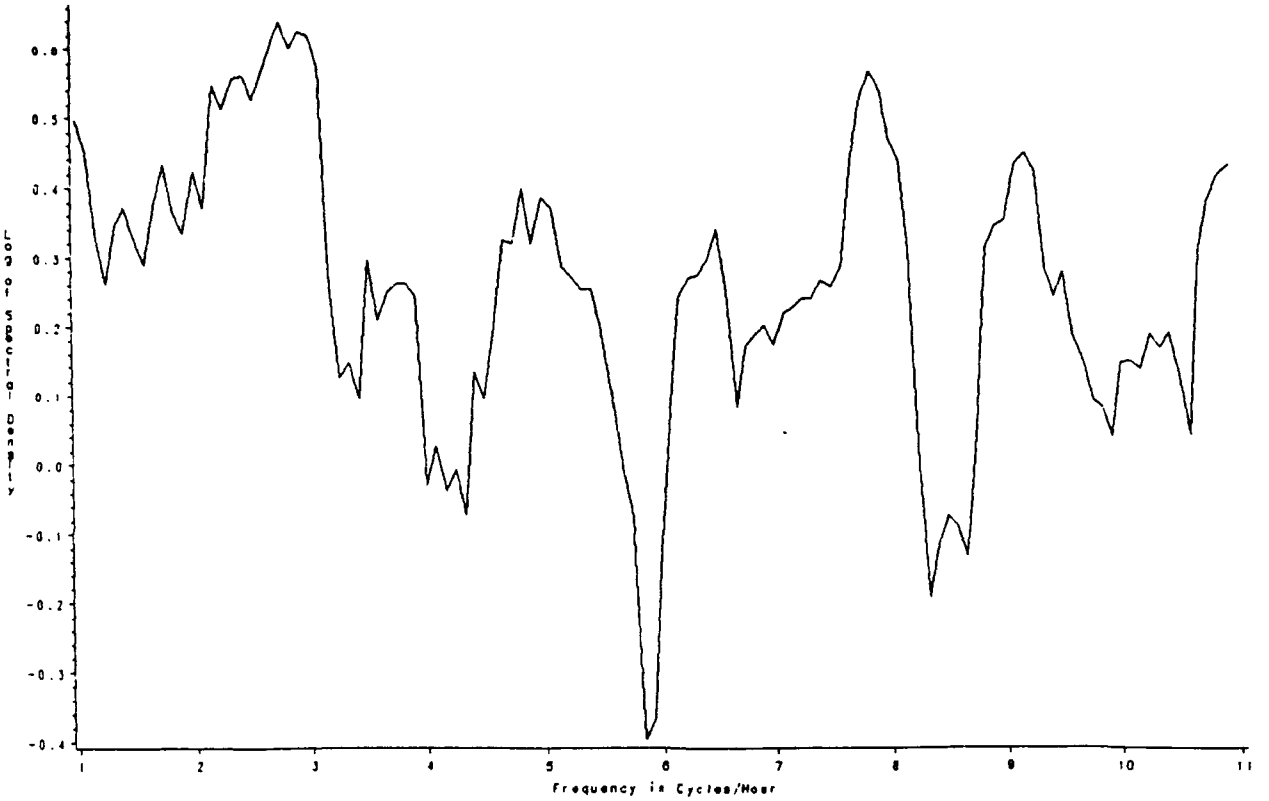

Figure 11. Power spectrum of Shemya wind speeds, 28-29 Sep 91 (1 < freq < 11).

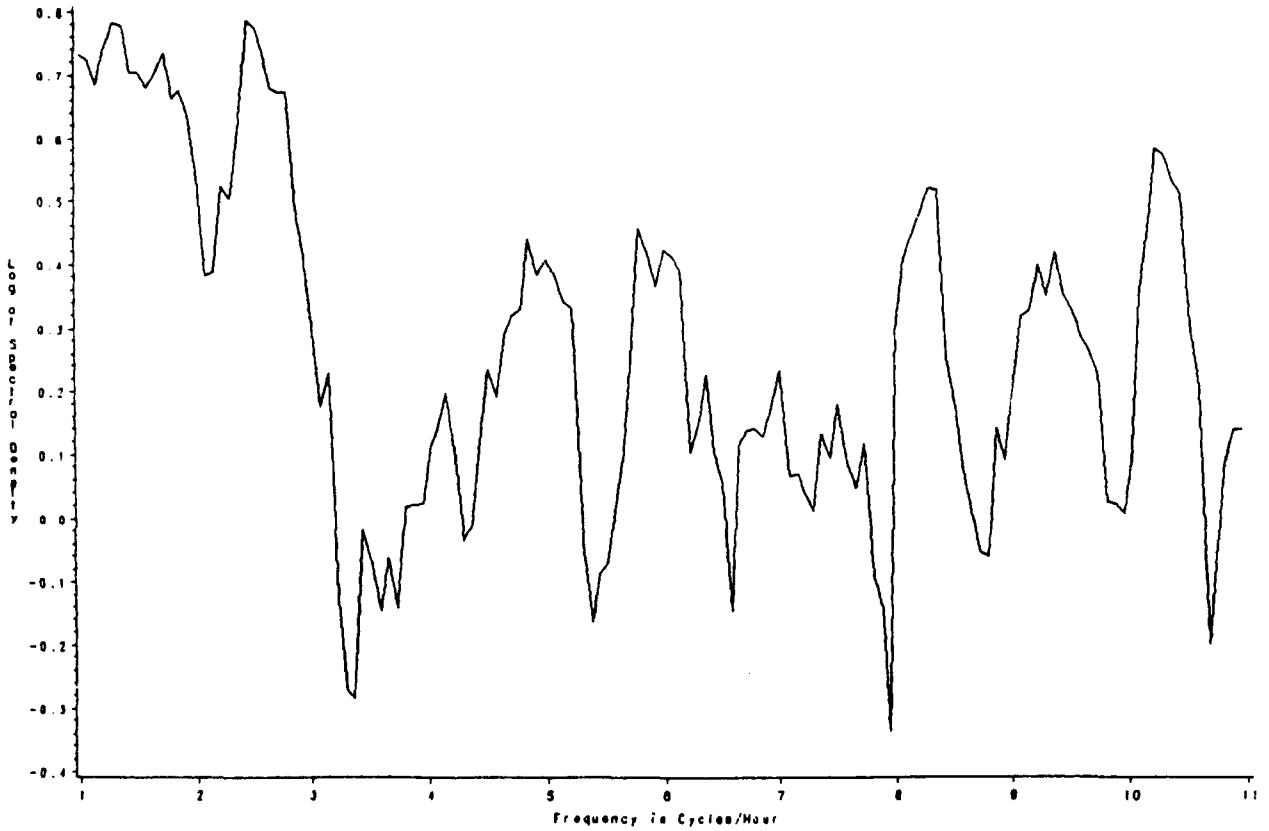

Figure 12. Power spectrum of Shemya wind speeds, 5 Oct 91, (1 <freq < 11).

4. CONCLUSIONS.

Based on the data analyzed in this study, no clear evidence of periodicity was found in wind speeds at Shemya AFB. After removing peaks in the spectra at very low or very high frequencies, the only peaks found to be significantly different from "white noise" were those with a period near 45 minutes from the 22-23 September data set. Since no corresponding peaks were found at this frequency among any of the other datasets, it should not be concluded that there is strong evidence to support a 45-minute periodicity in wind speeds at Shemya. Certainly no evidence was found to support the existence of a 10-minute wind speed periodicity.

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GLOSSARY

DNO	Operations Applications Development section of USAFETAC
OL-A	USAFETAC's Operating Location A, located in Asheville, NC
SAC/DOWX	Strategic Air Command/Directorate of Weather, Plans and Programs division
SAS	Statistical Analysis System. Fourth generation computer language used a USAFETAC
SPECTRA	A statistical procedure available in the SAS system, used to produce and analyze power spectra
SAS GRAPH	A graphics software package available in the sas system
USAFETAC	United States Air Force Environmental Technical Applications Center

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